Paleontologic Resources, Impacts, and Mitigation
Pacific Gas & Electric Pipeline 57C
Revised Route
San Joaquin County, California

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Date: 23 June, 2005

1 Introduction

1.1 *Disclaimer*

The geological conclusions presented in this report represent the unreviewed interpretations of the author alone, based on data from cited sources, and are intended only to aid in the assessment of the probable distribution and significance of paleontologic resources within the project area. Neither written or graphic representations of the subsurface geology should be used in the interpretation of geometric, physical, or engineering properties of the represented geologic units.

1.2 *Project description*

The new pipeline – designated Line 57C – would be approximately six miles long, extending from the McDonald Island Underground Storage Facility to Palm Tract. The entire pipeline would be constructed in the Sacramento-San Joaquin River Delta region, which is below sea level and consists of a network of rivers, waterways (both man-made and natural) and islands created through the construction of levees.

The pipeline will be placed in trenches about ten feet deep and 25 feet wide through approximately 35% of the planned route. The remainder of the pipeline will be routed below major waterways, the Empire Cut, Middle River, and Old River, using horizontal directed drilling (HDD) methods expected to reach depths of about 100 feet (Kleinfelder 2005).

1.3 *Paleontologic resources*

This report addresses the likelihood of the presence of significant paleontologic resources, their probable nature and distribution, the potential impacts of project–related activities on those resources, and preliminary plans to mitigate expected impacts.

1.3.1 Basic definitions

Paleontologic resources comprise fossils -- the remains or traces of once-living organisms preserved in sedimentary deposits (unconsolidated or semiconsolidated "soils" or sedimentary rocks) -- together with the geologic context in which they occur. Most fossil remains are the preserved hard parts of plants or animals, and include bones and/or teeth of once-living vertebrate animals, shells or body impressions of invertebrate animals, and impressions or carbonized or mineralized parts of plants (e.g. leaf impressions or "petrified wood"). Trace fossils include preserved footprints, trackways, and burrows of prehistoric animals. Paleontologic resources are non-renewable.

Paleontologic resources do not include man-made objects (artifacts) or human remains, though these may occur buried in younger sedimentary deposits. Such artifacts and remains are considered archeological resources, and are not considered in this report.

1.3.2 Probability of discovery

Under current criteria and standards established through the collaboration of government agencies (mostly federal) and scientists, the probability of discovery without the project is not considered a factor in the assessment of the existence or significance of paleontologic resources because:

1) this is usually impossible to predict,

2) from a scientific perspective, the destruction of unique information without attempts to avoid or at least minimize the loss is not justifiable. No matter where it is found, each fossil typically consitutes the only existing documentation of the geologic age and location of a particular individual plant or animal, so at least in this sense, it is unique. Its uniqueness is further enhanced when it is understood that a fossil (especially a vertebrate fossil) typically represents only a miniscule fraction of once-living individuals of its species whose identifiable remains escaped scavenging and destruction by weathering or stream transport, came to rest in settings which allowed long-term preservation, and wasn't subsequently destroyed by chemical or erosional processes. Association of fossils representing two or more species in a single locality or closely grouped localities allows broader kinds of inferences concerning e.g. paleoecology and the uses of fossils for identifying the ages of the sediment or sedimentary rock. Typically, no two fossil specimens or localities will yield identical information.

3) Cumulative impacts due to continuing growth of urban areas and large-scale energy and transportation infrastructure progressively constrain the area of traditional "natural" access (as by erosion) to the geologic and fossil record. This leaves man-made excavations as an increasingly valuable kind of access, even though each excavation can reveal specimens which otherwise would probably not have been found.

1.3.3 Significance

Different categories of fossils vary widely in their relative abundance and distribution, and not all are generally regarded as significant. Because of their rarity, vertebrate fossils, whether preserved remains or trackways, are classed as significant by virtually all state and federal agencies and professional groups that have addressed the question (California Public Resources Code Section 5097.5, US Bureau of Land Management 1986; SVP 1995).

The geologic context in which fossils occur can provide a great deal of information not recorded in the fossils themselves. Details of the sediments surrounding the fossils can be interpreted in terms of the relative ages of different fossil occurrences and the local environments in which the remains were originally buried. If the sediments include carbon-rich remains of plants or animals or volcanic ash deposits, it may be possible to bracket the actual age of the specimens using radiometric dating techniques. Radiometric dating cannot usually be applied directly to fossils older than about 40,000 years.

A more detailed discussion of significance and its assessment follows in Section 4 of this report.

2 Authorization

As a condition of project approval, the California Public Utilities Commission has required Pacific Gas and Electric Company to adhere to the statutes and guidelines of the California Environmental Quality Act (CEQA).

This report was prepared by C. Bruce Hanson under a subconsulting agreement with EIP Associates (EIP Project Number 11018-01) on behalf of their client, Trigon–EPC.

3 Laws, ordinances, regulations, and standards

The California Environmental Quality Act (CEQA) includes references to paleontology in its Appendix G, which defines significant effects of projects on paleontological resources, and Appendix I, which asks the applicant if the proposal would affect such resources. Appendix G states:

> "A project will normally have a significant effect on the environment if it will:
> …
> (j) Disrupt or adversely affect a prehistoric or historic archaeological site or a property of historic or cultural significance to a community or ethnic or social group; or a paleontological site except as a part of a scientific study;
> …"

The California Public Resources Code, (Division 5, Parks and Monument, Chapter 1.7 entitled "Archeological, Paleontological, and Historic Sites". Section 5097 to 5097.6) is more explicit and broader in applicability than CEQA, imposing sanctions for "unauthorized excavation, removal, destruction, etc., of … paleontological …features on public lands…". Under this portion of the statute, "public lands" include "…lands owned by, or under the jurisdiction of, the state, or any city, county, district, authority, or public corporation, or any agency thereof".

As the land affected by the project is not owned by or under the jurisdiction of federal agencies, federal laws do not directly apply to the project. However, as the Federal Land Policy and Management Act (FLPMA) and the Antiquities Act of 1906 include protection of paleontologic resources, several federal agencies have addressed questions of the definitions of paleontologic significance, providing guidance for those issues which are not addressed by California agencies. In particular, the US Bureau of Land Management has adopted explicit policies and criteria used in the management and assessment of paleontological resources within their purview (BLM 1969). Those criteria are discussed in Section 4.2.

Specific recommendations for mitigation of negative impacts on paleontologic resources are not included in either California state or US federal statutes, or in guidelines for ther application. Because fossils representing vertebrate animals (as opposed to fossils of plants or invertebrate animals) are generally recognized as significant resources, the Society of Vertebrate Paleontology has undertaken to provide uniform guidelines for recommended mitigation methods (SVP, 1995). In recent years, these guidelines have been broadly accepted as appropriate minimum standards and measures.

4 Paleontologic significance assessment

4.1 Definitions and rationale

Research based on fossils and their geologic context may emphasize their use as indicators of geologic time, records of anatomical, physiological, or behavioral details of extinct organisms, evidence of the course of evolution, or samples of former ecosystems.

4.1.1 Significance

As used in this report in reference to paleontologic resources, *significance* is assumed to mean the importance of a fossil specimen, locality, or geologic unit to the science of paleontology. The significance of a fossil specimen cannot be fully assessed until any specimens are collected, cleaned and repaired, and compared with data from previous investigations or previously collected specimens. However, the geographic and geologic setting of a body of sediment or sedimentary rock relative to known fossil localities can provide the basis for estimating the probable significance of any new fossil localities which may be found in that setting. Thus, if an area of interest is geographically distant from, or of a different age or paleoenvironmental setting from established, well-sampled localities, any new fossil localities in the area of interest are more likely to yield new scientifically valuable information.

Significance of a fossil does not depend on the size of the species it represents. Fossils of small vertebrates, such as rodents, insectivores, small birds, reptiles, amphibians, or fish may provide as much information about the age of the enclosing deposit and/or the environment that existed at the time as do those of large vertebrates. These small vertebrate fossils are sometimes collectively termed *microvertebrates*. Such fossils are commonly underrepresented in collections because they are less conspicuous, though they can occur in abundance in favorable deposits and can be recovered by wet or dry screening of the enclosing sediment.

4.1.2 Potential

A separate issue is the *potential* of a given area or body of sediment to include fossils. Information that can contribute to assessment of this potential includes: 1) the existence of known fossil localities or documented absence of fossils nearby and in the same geologic unit (e.g. "Formation" or one of its subunits), 2) details of the nature of sedimentary deposits (such as size of included particles or clasts, color, and bedding type) in the area of interest compared with those of similar deposits known elsewhere to favor or disfavor inclusion of fossils, and 3) interpretation of sediment details and known geologic history of the sedimentary body of interest in terms of the ancient environments in which they were deposited, followed by assessment of the favorability of those environments for the preservation of fossils.

The attribute of high potential for a given area does not reduce the significance of individual specimens or localities because:

1) Significance of a specimen or cluster of specimens cannot be fully assessed before preparation and comparison with other specimens. Each specimen/locality is unique in some way.

2) Some kinds of research questions relating to faunal changes through time can only be answered where abundant fossils and/or fossils from multiple stratigraphic levels exist, so individual fossils found in places where they are common can provide information useful to more different kinds of studies than would an isolated find.

4.1.3 Sensitivity

The *sensitivity* of a given area or body of sediment with respect to paleontologic resources is a function of both the *potential* for the existence of fossils and the predicted *significance* (as defined above) of any fossils which may be found there.

4.2 General Criteria

The state and federal statutes enacted for the protection of significant paleontological resources do not include criteria by which significance is defined, although not all fossils are considered significant, even by professional paleontologists. Some federal agencies, charged with management of paleontologic resources on federal lands under the dictates of the Federal Land Policy and Management Act (FLPMA), have therefore sought to clarify the definitions of paleontologic significance in close cooperation with paleontologic professionals and other interested parties. In the absence of similar guidelines provided by California state agencies, the federal guidelines have generally been adopted as applicable where California laws require protection of significant paleontologic resources

A set of explicit and relatively objective criteria for assessment of paleontological significance, compatible with the above considerations, has been developed by the US Bureau of Land Management (1969, revised 1998). These criteria lead to a ranking of geographic areas according to the probability of occurrence and the level of importance of fossils:

> **"Condition 1**: Areas that are known to contain vertebrate fossils or noteworthy occurrences of invertebrate or plant fossils.
>
> **Condition 2:** Areas with exposures of geologic units or settings that have a high potential to contain vertebrate fossils or noteworthy occurrences of invertebrate or plant fossils. The

presence of geologic units from which such fossils have been recovered elsewhere may require further assessment of these same units where they are exposed in the area of consideration.

Condition 3: Areas that are very unlikely to produce vertebrate fossils or noteworthy occurrences of invertebrate or plant fossils based on their surficial geology, igneous or metamorphic rocks, extremely young alluvium, colluvium, aeolian deposits, or the presence of deep soils. Anticipated depth of bedrock will aid in determining if fossiliferous deposits will be potentially uncovered during surface-disturbing activities. "

4.3 Methods and models

4.3.1 Data assembly

Information which has contributed to assessment of the probability of occurence and significance of fossils within the Line 57 project area has been assembled from three primary sources: 1) published geologic and paleontologic literature, including geologic maps, 2) museum records of known published and unpublished vertebrate fossil localities in the region, and 3) a project-specific geotechical report.

Bibliographic and internet searches resulted in a list of technical publications possibly relevant to assessment of paleontologic resources in the project area. Publications selected from this list were examined at the University of California, Berkeley libraries.

The University of California Museum of Paleontology (UCMP) at Berkeley has assembled extensive collections and locality records of vertebrate fossils, especially those from central California, since the late 1800's. Summary versions of these records have recently become available via the Internet, and queries of this database were made for locality and specimen records of appropriate geologic age within the five-county area surrounding the project site.

Kleinfelder, Inc. (2005) has produced a preliminary geotechnical report for the Line 57 Project. The Kleinfelder report, including seven bore logs from sites along the project route, constitutes the primary documentation of subsurface geologic conditions relevent to the goals of the present report. Kleinfelder, Inc. was not further consulted during production of this report, and is not responsible for the geologic interpretations presented here.

4.3.2 Interpretation

As discussed above, prediction of probable occurrence of fossils typically relies on three avenues of investigation: 1) The presence (or absence) of known localities in the general vicinity of the area of consideration and in the same geologic units, 2) correlation between the presence of certain features of sediments with the presence or absence of fossils, and 3) interpretation of details of the sedimentary deposits within the target area in terms of the ancient environments in which they formed and the likelihood of fossil preservation in these environments.

The first approach is limited in its application to the present analysis due to the unusual characteristics of the project area. The project site, within a large, low-relief delta, includes no nearby areas in which geologic or paleontologic evidence of prehistoric events can be directly examined at surface exposures of geologic units that are equivalent in both age and depositional setting. Though fossils may be numerous at depth, it is expected that fossil localities would not have been found and reported unless encountered in man-made excavations or borings, most of which have not been examined for fossils.

The pattern of known vertebrate localities in the five-county area (Solano, Yolo, Sacramento, Contra Costa, and San Joaquin Counties) surrounding the delta is consistent with these expectations. Although numerous Pleistocene localities are known at low elevations near the delta (especially to the west), only two (Big Break -- UCMP Loc. V87047, and Sand Mound Slough -- UCMP Loc. V65254) are within the central delta area, and both appear to have been discovered at relatively shallow modern excavations. Each locality has yielded only two specimens of large fossil vertebrates (mammoth and a new species of antelope; Richards and McCrossin 1991).

The bore logs reported by Kleinfelder (2005) do not note the presence of any fossils which may have been recovered in the cores. This cannot be taken as an indication that fossils are absent: As fossils representing large vertebrates are volumetrically rare, the probability that they would appear in the cores, even if present in the subsurface, is very small. Small vertebrate fossils, such as those of rodents, reptiles, birds, and most fish, would probably have been overlooked if not specifically searched for, and may not be reported in any case as they would be of no relevance to the engineering properties of the enclosing sediment.

Although many of the known localities peripheral to the delta are similar in age to deposits within the project impact area, the depositional environments of most of these were not closely similar to those expected in the delta subsurface. The known localities typically occur in alluvial fan or subaerial floodplain deposits, whereas the sediments underlying the project area were deposited in the delta regime: in river and stream channels and natural levees and in frequently or continuously flooded ponds. Inference of the probability of fossil preservation within the project area based on occurrences in other depositional environments is not strictly valid.

A cluster of recorded older Pleistocene vertebrate fossil localities near the western boundary of San Joaquin County, mostly in cuts of the Delta Mendota Canal and Interstate 580, do appear to reflect deltaic rather than floodplain conditions. Though older than deposits expected in the impact zone of the Line 57 Project, these rather richly fossiliferous deposits probably resemble, in composition and fossil content, at least some of the subsurface sediments within the impact area.

Adjacent to San Francisco Bay, in and near the cities of Rodeo and Pinole, another cluster of very rich Pleistocene localities (Wolff 1971, 1975) originated in a delta setting which, though much smaller than the Central Valley delta, documents the potential for preservation of vertebrate faunal remains in a comparable setting. This delta extended about 2.5 kilometers along the shoreline and terminated in the open bay. Despite the differences, sedimentary deposits enclosing the localities closely parallel those seen in the larger, closed delta deposits underlying the project site (Kleinfelder 2005). Bulk samples from selected sandy channel sites typically yielded about 50 or more vertebrate fossil specimens per 100-pound sample or about 0.8 cubic feet (Wolff 1971).

Lack of detailed data characterizing the subsurface sediments also limits the applicability of the second approach, correlation of sedimentary features with fossil abundance. Bore logs, such as those presented by Kleinfelder (2005), recorded primarily to characterize engineering properties of subsurface “soils” (unconsolidated or semi-consolidated sediments which may or may not include localized evidence of ancient soil development) do not typically include descriptions of the kinds of details which may be known to correlate with the presence or absence of fossils. The information provided by these logs does not provide a reliable basis for empirical correlation of sediment characteristics with the presence or absence of fossils.

Given the limited record of known vertebrate fossil localities equivalent in both age and depositional environment to those of the project area, assessment of probable fossil potential in the affected area must be based largely on the inference of depositional (and life) environments from the available well core data and an established general history of deposition in the larger region as presented in the geological literature. This must be followed by assessment of the favorability of these environments for the accumulation of animal remains, the kinds of organisms likely to be represented, and the probability of preservation of their remains.

4.4 Historical geology of the project area

Assessment of the potential for paleontologically significant resources depends on general understanding of the events and processes which created the local geologic and paleontologic record.

The Central Valley of California, including the Sacramento and San Joaquin River Valleys and the delta between them, owes its existence to about 175 million years of repeated, slow downwarping of the earth's crust below it (Atwater 1982). Because the valley floor was near or below sea level for much of its geologic past, sediments carried by streams from the surrounding mountain ranges tended to accumulate in the low-gradient valley, occasionally burying remains of plants or animals that had accumulated on the surface. Cretaceous to Recent marine and non-marine deposits have accumulated in the valley to depths of five to ten kilometers (Atwater 1982).

Exceptions to this general buildup of sediments occurred during several periods in the geologic past when sea level fell below the approximate elevation of the valley floor. Areas which had previously accumulated flood-borne sediments would then undergo soil development or erosion, though parts of the preceding sedimentary deposit would remain, usually near the adjacent higher lands.

Though often called the "Ice Age", the Pleistocene Epoch included interglacial periods with temperatures not unlike those of today. During the Pleistocene Epoch, which began about 1.8 million years ago (Prothero 1998, Bell *et al* 2004), worldwide sea level fell and rose more than a dozen times as continental glacial ice accumulated and melted (Atwater 1982). Several of the major sea-level lowstands inhibited deposition in areas nearer the flanking hills, and promoted development of the ancient soils and geomorphic terraces.

The major late Pleistocene geologic units in peripheral non-deltaic deposits within the Great Valley are primarily identified and defined by these preserved ancient soils and terraces. The fossil soils on ancient fan and overbank flood deposits near mountain foothills have been identified and mapped along both sides of the Central Valley (Shlemon 1971, Atwater 1982, Helley and Harwood 1985, Lettis 1988).

Time-equivalent deposits within the delta regime cannot be recognized by the same criteria. Much of the area now occupied by the delta probably "dried up" during the low seastand intervals, and erosion and soil development predominated while rivers and streams were constrained to modestly entrenched valleys with narrow floodplains. As the dynamic delta environment returned, however, the record of any soils that may have developed would likely have been soon eroded away as the meandering distributary channels migrated laterally. As a result, the features that define the formations outside the delta can be recognized only rarely within the deltaic deposits. Estimates of the ages of the delta deposits, however, have been made by projection of geologically documented ancient stream channel deposits of the Mokelumne River into the delta area (Shlemon 1971).

With the end of the last glaciation, and by most definitions also the end of the Pleistocene, seas again rose to their present level and led to the development of the historic (but pre-agricultural) features of the delta: anastomosing, often meandering natural channels, natural levees (often breached) flanking the channels, periodically or permanently flooded interdistributary depressions bounded by the levees, and oxbow lakes and ponds in the depressions left by abandoned channels. The interdistributary depressions supported growth of dense marshy vegetation whose remains built up as thick mats of peat. Because the beginning of peat deposition occurred near the end of the last world-wide glaciation, the age of the lowest peat should also approximate the date of the end of the Pleistocene. Carbon-14 dating of the oldest recognized peat deposit has yielded an age estimate for this event of approximately 10,700 years (Shlemon 1971). This generally agrees with other published dates for the end of the Pleistocene (and beginning of the "Recent" or "Holocene" Epoch).

The end of the Pleistocene also marks a time of extinction of many of the larger mammals that had lived for thousands of years throughout North America. Elephant relatives (mammoths and mastodons), camels, horses, tapirs, giant ground sloths, saber-tooth cats, dire wolves, and brush ox were among the former California residents whose remains have not been found in deposits younger than late Pleistocene (except for horses which early Spanish explorers reintroduced into North America about 300 years ago).

Following the Pleistocene Epoch, the delta surface was occupied by marshes and probably large ponds bounded by natural levees which formed along river channels.With human settlement since the mid-1800's, reinforcement of these levees allowed reclamation of former marshland and ponds for agriculture, and dredging improved access for water-based transportation. These operations involved redistribution of the natural sediment deposits, leaving historically disturbed sediments of varying thickness near the present delta surface.

4.5 Site-specific significance assessments

Well core data assembled from the project area (Kleinfelder 2005) are consistent with published models of late Pleistocene to Holocene deltaic deposition and erosion in the immediate area (Atwater 1982, Lettis 1988, Shlemon 1971). The diverse sediments documented in the bore logs are those expected from deposition in ancient channels (typically gravels and well-sorted sands), natural levees (silt and sand), and oxbow lakes and interdistributary depressions (clay, silt, and peat). In the western part of the project area, mostly in and near Palm Tract, eolian (wind-borne) sands and silts also contributed to the thick Pleistocene and Holocene deposits. Rapid lateral changes in the composition and thickness of individual sedimentary units reflect the diversity of very local depositional environments and changing positions of the controlling channels through meandering, cutoffs, and channel convergence and divergence.

4.5.1 Historically disturbed sediments

Sediment or rock that has been displaced from its original area of deposition, as through human activity (e.g. historic fill), has lost the contextual information it may have provided concerning the age and geographic location of any fossils that may have been originally included. It is also likely that any included fossils would have been destroyed during past excavation, transport, and compaction. Such reworked deposits are therefore not considered sensitive paleontologic resources: Condition 3 by the BLM criteria .

4.5.2 Peat deposits

The uppermost undisturbed geologic unit within the project area consists in large part of peat, the remains of plants which accumulated in almost permanently wet areas where their decomposition was far slower than in nearby dry areas. The geologic map by Helley and Graymer (1997) following Atwater (1982) shows the entire project area as being directly underlain by Holocene peat and peaty mud with scattered small deposits of eolian sand on Palm Tract, just west of the Line 57 route. As discussed above, the peat deposits date from post-Pleistocene time: any animal remains which might be preserved in the peat would be of limited paleontologic significance, and may not qualify as fossils if the definition is restricted to remains of pre-Holocene age. The rather acidic peat deposit (pH 5.3: Kleinfelder 2005, p. 13) would not favor preservation of bones in any case (Retallack 1988). These conclusions lead to an assessment of Condition 3 ("very unlikely to produce vertebrate fossils…based on…extremely young…deposits ") for the peat unit according to the BLM criteria.

4.5.3 Younger inorganic delta deposits

Five of the seven bore logs reveal the base of the peat at depths between about 14 and 17 feet, while cores near the middle of Bacon Island and on McDonald Island show thinner peat deposits with higher bases, three to eight feet below surface. Atwater (1982) indicates the presence at the surface of two abandoned late Holocene river channels near the middle of Bacon Island: The thinning of the peat deposits here may reflect the local continuation of channel and levee deposition here at the same time that peat was accumulating in the more widespread interdistributary depressions. Alternatively, at least some of these deposits may, at least in part, represent topographically high remnants of Pleistocene deposits that were not eroded as much as the adjacent lands. These deposits are therefore regarded as potentially sensitive (Condition 2).

4.5.4 Older inorganic delta deposits

Sediments below the peat and younger inorganic deposits, all of which were deposited in various delta settings and are inferred to date to the Pleistocene, present a much greater probability of enclosing significant vertebrate fossils. The delta environment undoubtedly supported a richer and more diverse vertebrate fauna than would be expected in the better-sampled fan and floodplain environments in the region. Permanent water and probably abundant herbs, bushes, and trees could support fish, amphibians, birds, and aquatic and browsing mammals which would be rare or absent in the drier peripheral areas. Bones and teeth of these animals also would have accumulated in shaded, moist, or submerged settings, all of which would have favored their preservation and burial. In non-deltaic settings, vertebrate hard parts generally would have been more exposed to destruction by carnivores and scavengers, and would have deteriorated more rapidly due to exposure to air, sunlight, rainfall, and daily changes in temperature and humidity (Behrensmeyer and Dechant Boaz 1980, p. 88), reducing the probability that they would have remained on the surface long enough to be buried during flooding: Still, vertebrate fossils from contemporary non-deltaic environments have been found in many sites just outside the delta.

Other factors favoring accumulation of vertebrate remains in the delta setting include high seasonal populations of migrating birds and possible miring of large mammals in areas of deep mud. During major flood events, hundreds of which must have occurred during the late Pleistocene interval, many of the land animals which had occupied the vegetated natural levees would have become stranded and drowned, and the muddy floodwaters may well have clogged the gills of many species of fish. Floating carcasses, partial carcasses, or disarticulated bones of upstream riparian animals transported into the delta during such flood events would have been trapped by protruding vegetation or their transport stopped due to the downstream decrease in river gradient and shear stress (Hanson 1980). Changes in world-wide sea level would have affected the extent of brackish-water intrusion, leading to radical changes in the flora and fauna of the delta, and increasing the potential diversity of the fossil record. Soil acidity in the sub-peat delta deposits is very low (pH 6.7 or nearly neutral in a composite sample from 10 to 15-foot levels: Kleinfelder 2005), so bones would not have been dissolved after burial (Retallack 1988). Relatively rapid sediment deposition in the delta appears to be the single factor that may tend to reduce volumetric fossil concentration here compared with nearby floodplain deposits, though this would also favor the quality of preservation.

The significance of any fossils that may be present here would be enhanced by several factors inherent to the unique delta environment and the age range of the deposit. There exists a reasonable expectation that vertebrate fossils found in the sub-peat deposits would include many species that did not range outside the delta environments, and have not been found in contemporary deposits elsewhere in the Central Valley. Endemic and widespread vertebrates of about 100 different species may have inhabited the area. Another factor is the probable presence of radiometrically datable materials – plant remains buried in the same stratigraphic sequence which could be dated by the carbon-14 method. This method is applicable to plant remains less than about 40,000 years in age, and would be useful for obtaining dates of sediments and their enclosed fossils. Bones and teeth can also yield carbon-14 dates if they retain enough organic carbon. The possibility of numerous fossil samples from different levels and local environments within the deposit, coupled with the expected independent radiometric dating controls, would make this an ideal area for studies relating to the nature and causes of the major extinction event near the end of the Pleistocene, a subject still much debated.

Based on Shlemon's (1971) extrapolation of Mokelumne River channel and fan deposits to points about six to eight miles north of the project area, most of the sediment within about 60 to 90 feet of the surface but underlying the peat would be expected to be at least partly equivalent in age to the Modesto Formation. An abrupt upward coarsening of sediments near these levels in the Kleinfelder (2005) cores may reflect pre-Modesto erosion and renewed deposition early in the last interglacial stage. The Modesto Formation, recognized at slightly higher elevations in the Sacramento Valley and eastern San Joaquin Valley, is late Pleistocene and possibly earliest Holocene in age, about 118 thousand to 9.5 thousand years. In the western San Joaquin Valley, deposits of comparable age are termed the Alluvium of San Luis Ranch (Lettis 1988).

If this correlation is correct, the deepest portions of the deposit reported in the 101-foot Kleinfelder (2005) bore logs would correspond in age to the upper part of the Riverbank Formation (also late Pleistocene, but dating to more than 131 thousand years: Lettis1988), but would also represent deltaic deposits. Contemporary alluvial fan and channel deposits within this formation near Sacramento have yielded numerous vertebrate fossils from at least three known localities (UCMP records, Hilton 2000, C.B. Hanson unpub. data).

4.5.5 Assessment summary

Although specific locations and depths of unseen fossil localities can not be predicted, the above considerations support the assessments that: 1) significant paleontologic resources probably do not exist within the Holocene peat and peaty mud deposits in the upper 14 to 17 feet of most of the project area except possibly in portions of Bacon and McDonald Islands where the peat deposits are thinner; and 2) there is a high probability that significant paleontologic resources (Pleistocene vertebrate fossils) do exist within sediments below the peat at least down to the maximum depth of anticipated horizontal directed drilling.

Strict application of the criteria erected by the US Bureau of Land Management (Section 4.2) dictate that sediments below the level of the lowest peat deposits be classified as Condition 2, as the presence of vertebrate or other significant fossils has not been directly proven. In view of evidence presented above supporting the high probability of the presence of vertebrate fossils and factors which tend to enhance the significance of any fossils present, the entire body of sediment below the surficial peat deposits is assessed to merit high paleontologic sensitivity.

5 Project-level impact assessment

5.1 Spatial distribution of project impact zone and paleontologic resources

5.1.1 Area and zone of potential effect

For purposes of this report, the area of potential effect (APE) includes the surface footprint of project operations involving excavation. The zone of potential effect (ZPE) includes all natural sediment deposits (including peat) below the APE which will be displaced by any project operations. Major project operations expected to displace sediment include trenching, drilling (HDD), and installation of surface tanks or excavation of bore pits at drilling entry and exit points. Clearing and grading, excavations to accomodate new structures or other installations, and small-scale utility trenching may locally displace natural sediment.

The ZPE thus includes sedimentary deposits initially to be removed from approximately four miles of pipeline trench in five segments, 2.5 miles of HDD in four segments, unknown dimensions of bore pits, and any localized excavations. Assuming trench depth of 10 feet, 1:1 slopes, and a three-foot-wide flat area at the trench bottom, nearly 120,000 cubic yards will be disturbed by trenching. Slightly more than 1,500 cu. yds of sediment will be disturbed directly by planned HDD to accomodate a 24" pipe. Disturbance due to any needed bore pits, surface tanks, or local facilities has not yet been quantified.

5.1.2 Distribution of paleontologic resources

Geological deposits that will be encountered along the proposed pipeline route mostly fall into one of two categories of differing composition, age, depth, and paleontologic sensitivity.

Recent agricultural, levee maintenance, and road construction activities have undoubtedly disturbed or contributed to the uppermost sedimentary deposits throughout much of the project area. The depth of these non-natural deposits is expected to vary considerably across the site, but all such deposits will be underlain at depth by the widespread peat deposits. These historically disturbed or added bodies of sediment are not paleontologically sensitive.

Along most of the route, the uppermost deposits below the historically disturbed sediments consist mostly of peaty mud and peat, the partially decomposed remains of plants, primarily reeds and tules, that had accumulated in the delta marshes before the initiation of agriculture in the area. Bore logs show that the peat deposits typically extend downward to about 14 to 17 feet below the existing surface, but extend to a depth of only three to eight feet on a portion of Bacon Island. The peat deposits date to the Holocene Epoch (less than about 10,000 years) and do not provide a favorable chemical environment for preservation of vertebrate remains. The peat and peaty mud are not regarded as paleontologically sensitive.

Sediments below the peat deposits and extending beyond the 100-foot-deep bore logs (Kleinfelder, 2005) are mostly inorganic and include gravel (very minor), sand, silt, and clay and various mixtures of these. Each of the seven reported bore logs records a different sequence of sediment types, reflecting a history of complexly shifting distributary channels, levees, and interdistributary ponds and marshes. As any of the represented depositional environments are well-suited to the accumulation and preservation of vertebrate fossils, the entire body of sediment below the base of the peat and at least to the maximum anticipated depth of project-related drilling is regarded as paleontologically sensitive.

5.1.3 Zone of potential impact

The project zone of potential impact will affect deposits in sensitive, possibly sensitive, and non-sensitive categories.

By far the greatest volume of deposits to be displaced by the project occur within the non-sensitive near-surface historically disturbed “fill” and older peat deposits whose base falls below the anticipated 10-foot depth of the pipeline trench through most of its proposed length.

Exceptions occur in two areas: 1) at the east end of the proposed pipeline route, in the vicinity of the compressor station on McDonald Island, where Boring B-6 (Kleinfelder 2005) encountered the base of the peat at a depth of 8.5 feet; and 2) in the central part of Bacon Island including the temporary use areas adjacent to HDD input points for the bores under Old River and a drainage ditch.Ten-foot-deep trenches in these areas will encounter one to eight feet of silty sand and organic silty or sandy clay below the peat deposits (Kleinfelder 2005). These probable levee and abandoned-channel fill deposits may be mostly Holocene in age (Atwater 1988 maps Holocene channels at the surface here), but could partly include high-standing remnants of Pleistocene age. Pending additional information, which may not be available until these deposits are excavated, they must be regarded as possibly sensitive.

The only project operations presently known to affect sensitive deposits are those related to HDD. The drilling operation itself will extend deep into inorganic deposits known to be of Pleistocene age and which have a high potential to include vertebrate fossils. If bore pits at either the input or output ends of the HDD bores extend below the local levels of the peat deposits or the inorganic deposits of uncertain age, they will also entail disturbance of the sensitive units.

5.2 Project operations and their resource impacts

Geographic and depth limits of various degrees of impact significance will depend on final engineering plans.

5.2.1 Clearing and grading

Preparatory clearing and grading of the areas of proposed trenching, ancillary facilities construction, or temporary use areas will affect only near-surface deposits. In most cases, these consist of previously disturbed surficial sediments or peat, neither of which is paleontologically sensitive.

No negative impacts are expected to result from clearing and grading operations.

5.2.2 Trenching

Trench excavations are expected to disturb a large volume of natural deposits. Anticipated trench dimensions of 10-foot depth and ¾:1 to 1:1 lateral trench slopes (Kleinfelder 2005) will affect mostly the natural (pre-1850) non-sensitive peat deposits.

Inorganic deposits (lacking peat) fall below the peat, but within the expected trench depth in the central part of Bacon Island crossing and on most of Segment 3 on McDonald Island. These deposits include silt and silty or sandy clay, suggesting natural levee and interdistributary pond origin. As the deposits predate at least the upper parts of the Holocene peat, and are presumably less acidic, they hold the potential to include significant Pleistocene vertebrate fossils. Because of the uncertainty of the age of these deposits, but in view of their composition and apparently favorable origin, they are regarded as potentially sensitive.

Negative impacts to paleontologic resources may result from trenching in parts of Bacon Island and McDonald Island.

5.2.3 Horizontal directed drilling (HDD)

Horizontal directed drilling to accommodate the 24" pipe below waterways will displace approximately 1500 cubic yards of non-sensitive peat, potentially sensitive levee and pond deposits, and sensitive Pleistocene delta deposits of varied composition.

The non-sensitive and potentially sensitive units near the present surface together comprise less than 10% of the anticipated volume of sediment to be disturbed by HDD.

The remainder of anticipated HDD-related disturbance falls within the sensitive deeper Pleistocene delta deposits and will total more than 1300 cubic yards. If vertebrate fossil abundance in just one percent of these deposits approaches that seen in the smaller delta deposits near Pinole and Rodeo (discussed in Section 4.3.2), several tens of thousands of specimens would be expected to be included within the bored volume. The mechanics of HDD would probably result in destruction of most or all of these fossils, although this has not been proven.

Significant negative impacts to paleontologic resources are expected to result from HDD in areas where bores exceed 15 feet below the present surface.

5.2.4 Bore pit excavation or surface tank emplacement

Engineering techniques that will be employed at HDD bore input and output sites have not yet been specified, but will affect the extent of impacts on paleontologic resources and potential for mitigation. Excavations associated with either of these techniques that extend below the base of the non-sensitve peat unit may result in impacts to paleontologic resources.

5.2.5 Ancillary facilities construction

Details of construction of project-related structures other than those discussed above have not been finalized, but excavations related to such structures presently appear unlikely to disturb sensitive units, and few or no negative impacts are expected.

6 Mitigation

The constraints presented by the horizontal and vertical distribution of sensitive paleontologic resources and the proposed engineering techniques of project pipeline construction limit or preclude employment of mitigation measures typically effective for projects of this scale, such as visual monitoring of excavations in sensitive deposits and screen-washing samples from selected exposed geologic units to recover microvertebrates. There appear to be few precedents for mitigation of significant paleontologic resources impacted by horizontal directed drilling operations. Projects within California involving larger-diameter tunnelling in otherwise comparable circumstances, such as parts of the Los Angeles subway system and the Inland Feeder Project, were required under CEQA to be mitigated through monitoring, but tunnel walls and excavated materials were accessible in those cases.

The effectiveness and practicality of possible measures listed below will depend largely on engineering details not presently available. These methods could yield offsetting benefits to the science of paleontology and may mitigate project impacts to insignificant levels.

- Direct visual monitoring of trench excavations in those areas (McDonald Island and parts of Bacon Island) where trenching extends below the near-surface peat unit and into potentially sensitive deposits;

- Screen-washing sample volumes of the return drilling mud from HDD operations;

- Arranging for access by qualified paleontologists to existing or future core samples produced for the project for research purposes such as investigations of changes to local microvertebrate, pollen, and/or micro-invertebrate assemblages through the late Pleistocene.

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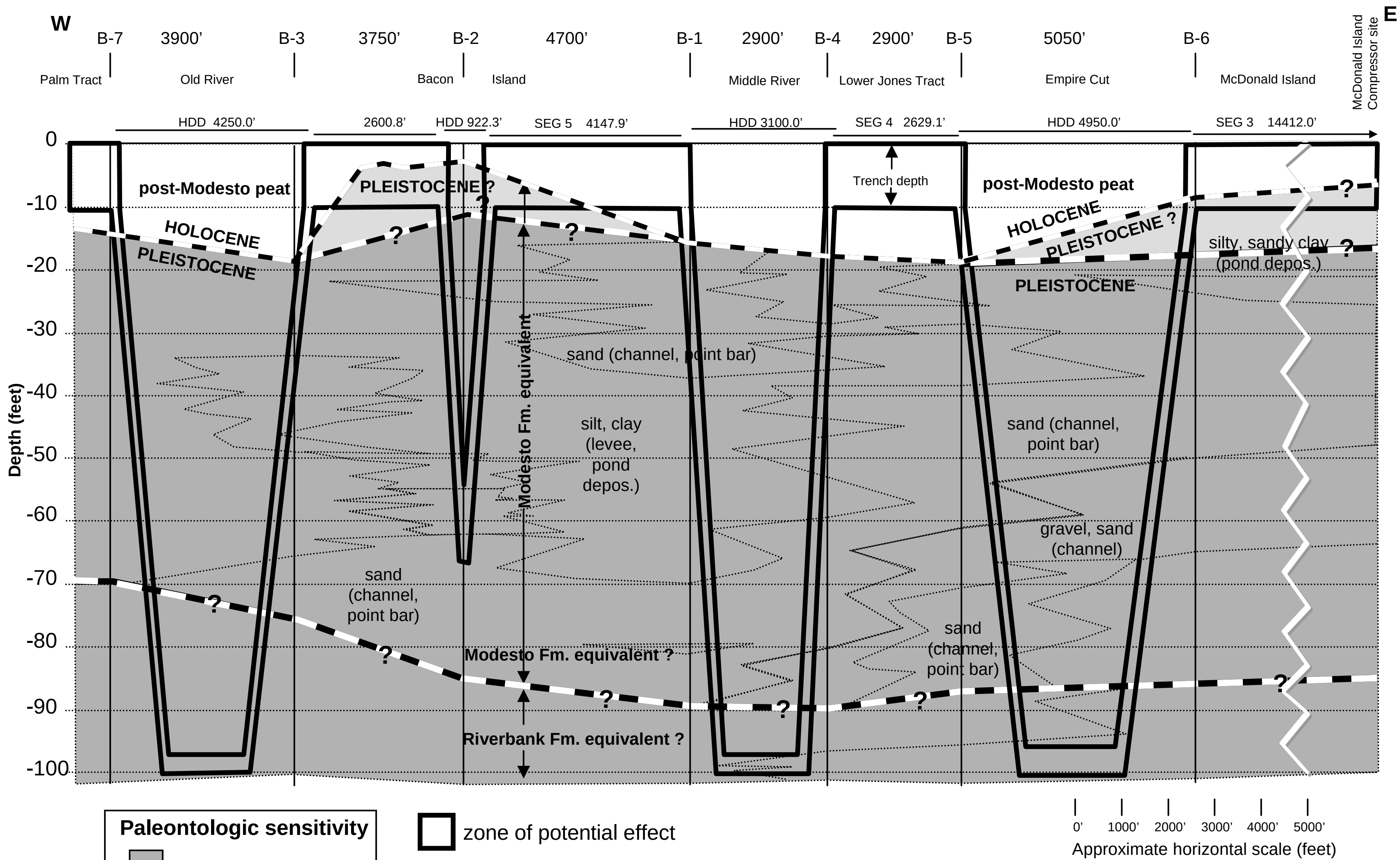
Figure 1. Graphic paleontologic sensitivity section showing approximate horizontal and depth distribution of significant, potentially significant, and not significant subzones of the area of potential effect. Section is through points of bore logs provided by Kleinfelder 2005 and is approximately parallel to but not directly along proposed pipeline routes or alternates. Not to scale.



Paleontologic sensitivity

- sensitive
- potentially sensitive
- not sensitive

B-1 through B-7; Bore logs (Kleinfelder 2005)

This diagram is intended for illustrative purposes only, and represents approximate geologic interpretations. Not intended for engineering purposes.

Figure 1. Vertical distribution of paleontologically sensitive units